Utilization of the Irradiation Holes in HANARO

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Abstract. HANARO has been used for radioisotope production, material and fuel irradiation tests, beam application research and neutron activation analysis. In the initial stage of a normal operation, the usage time of the irradiation holes located in the core was less than 40% of the reactor operation day. To raise the number of users and utilization areas of the irradiation holes, equipments and facilities have been developed such as various capsules. Starting with the capsule containing MoO_3 in 1999, the development of the capsule for an Ir-192 production contributed to the utilization of the irradiation holes in the core. Another area for increasing the utilization of HANARO was the fuel irradiation tests to develop new fuels. Various fuel tests have been performed. The major fuel tests were U_3Si fuel produced by an atomization process, a rod type U-Mo fuel for a new research reactor fuel, U-Zr fuel, a large grained UO_2 pellet developed for a high burn-up in KAERI. As a result of the steady efforts to improve HANARO's utilization, the usage time of the irradiation holes is more than 90% of the reactor operation day.

1. Introduction

The HANARO is an upward flowing light water cooled, heavy water reflected open-tank-in-pool type research reactor of $30MW_{th}$. Its first criticality was achieved on Feb. 8, 1995 and the normal power operation started from Jan. 1996. Since 1996, HANARO has been widely used for radioisotope production, material and fuel irradiation tests, beam application research and NAA(Neutron Activation Analysis). The reactor core is composed of an inner core inside an inner shell of a reflector tank and an outer core outside the inner shell as shown in Fig. 1. The inner core has 23 hexagonal and 8 circular flow channels seperated by flow tubes, while the outer core has 8 circular flow channels. The fuel assemblies are loaded into the hexagonal and circular flow tubes except three hexagonal holes(CT, IR1 and IR2) in the inner core and four circular holes(OR3～OR6) at the outer core. These three hexagonal and four circular holes are reserved for the irradiation tests in the core. Twenty holes including two NTD(Neutron Transmutation Doping) holes, a LH(Large Hole) and NAA holes are located in the reflector tank. The level of neutron flux in the irradiation holes is described in Table 1. The fuel and material irradiation tests that require a long irradiation time are performed by using the seven holes where the forced circulation of a core flow exists. But the targets to produce RI(Radio Isotope) with a short half life are mainly irradiated in the holes at the reflector tank where a natural convection of the pool water is available. In this paper, the status of utilizing the irradiation holes located in the core region and efforts to raise the number of users and utilization areas are described.

Table 1. Irradiation holes in HANARO

Region	Site	Number of holes	Avg. thermal flux(n/cm^2sec)	Avg. fast flux(n/cm^2sec)
Inner core	CT	1	3.0×10^{14}	$1.4x10^{14}$
	IR	2	$2.7x10^{14}$	$1.3x10^{14}$
Outer core	OR	4	$2.0 \sim 2.5 x10^{14}$	$1.2 -1.5x10^{13}$
Reflector tank	IP	17	$1.8x10^{13} \sim 1.3x10^{14}$	$2.0x10^{9} \sim 1.5x10^{12}$
	NTD	2	$3.7 \sim 4.0x10^{13}$	$7.7x10^{10} \sim 1.0x10^{11}$
	LH(Large Hole)	1	$7.4x10^{13}$	$4.7x10^{11}$

2. Utilization of the irradiation holes in the core

In the initial stage of a normal operation, the utilization of the HANARO was not active. The reason was that the development of equipments such as a capsule and rig for the irradiating material, RI targets and test fuel was delayed. Fig. 2 shows the ratio of the utilization of the irradiation holes in the core from 1996 to 2006. Fig. 3 shows the ratio of the occupied days of the irradiation holes in the inner core and outer core to the reactor operation days. In 1996, when the normal operation started, two kinds of tests had been performed at the irradiation holes in the inner core. One was the HANARO structure material test using a non-instrumented capsule, the other was the HANARO fuel test as the HANARO fuel qualification program at a high power that was required to resolve a conditional licensing prerequisite[1].

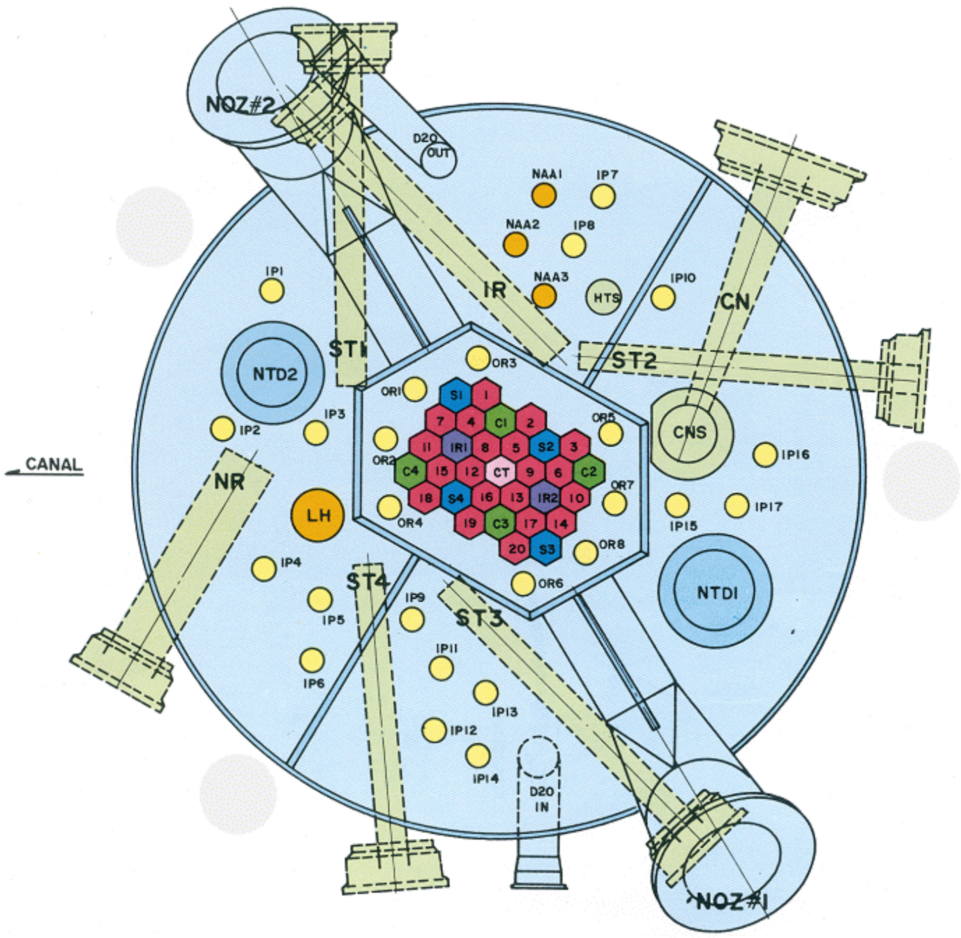

FIG. 1. The Plan view of HANARO

For the utilization of the irradiation holes, the equipments and facilities have been developed. The capsule for a RI production at holes in the reflector tank was developed easily because the coolant flows by a natural convection. But in the case of the capsules using holes in the core, a locking device should be provided to prevent an inadvertent removal during a power operation and a fixing device to reduce the vibration of the guide tube for an instrument such as a thermo-couple and SPND(Self Powered Neutron detector) by a coolant flow[2]. The development of these capsules increased the utilization of the irradiation holes. The instrument capsule for a material test requiring a high fast and thermal flux condition enlarged the irradiation areas.

During developing the various capsules to use in the irradiation holes in the reflector tank and core, the test fuels manufactured for a localization of the HANARO fuel had been irradiated until 1998. In 1999, the first capsule containing MoO_3 for a RI production was loaded in the OR hole. The capsule for the Ir -192 production was loaded in the middle of 1999. The test fuel is usually loaded in the OR holes with a high thermal neutron flux. But, as a demand for the fuel test increased, the capsule for producing Ir-192 at the irradiation holes(IR1, IR2 and CT) located in the inner core was developed in 2001. The instrument capsules for a material test accelated the usage of the iradiation holes in the inner core. The development of the RI capsule for producing Ir-192 and the instrument capsule for a material test requiring the high neutron flux condition contributed to the continuous usage of the irradiation holes in the center area of the core. From 2002, the utilization of the irradiation holes in the core was settled down. Fig. 4 shows the ratio of the fuel and material irradiation test for the total irradiation tests. From 2001, most of the material and RI production in the graph is RI production, especially, Ir-192 production.

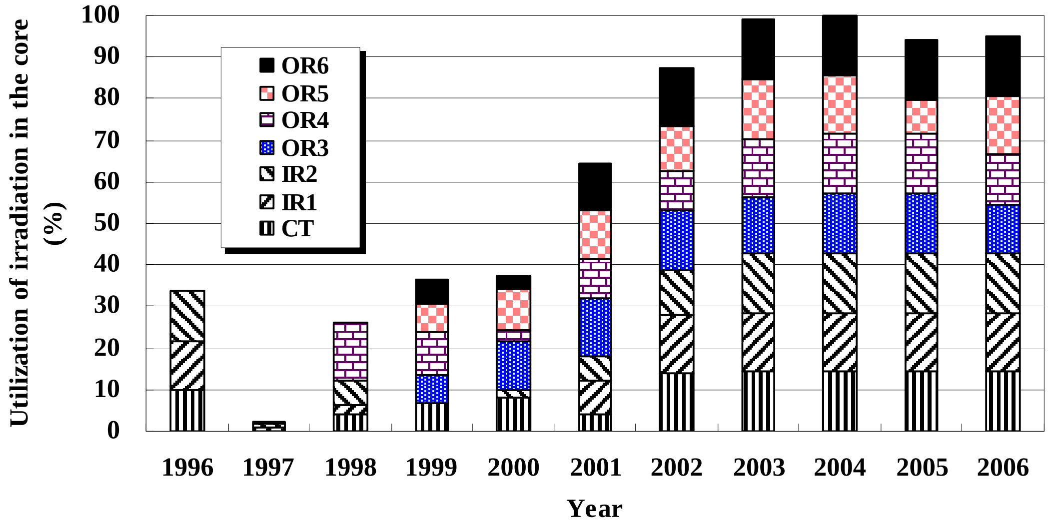

FIG. 2. The status of utilization of the irradiation holes in the core

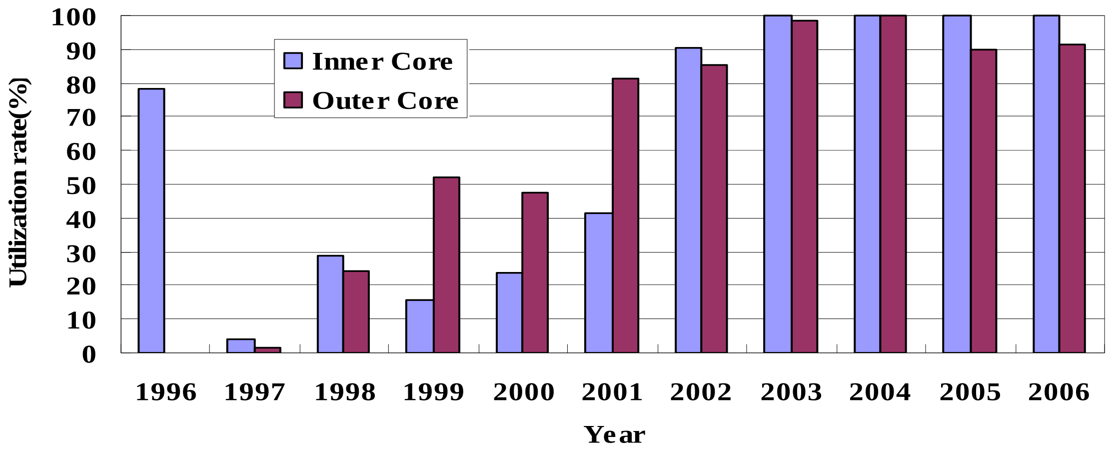

FIG. 3. The ratios of the occupied days of the irradiation holes to reactor operation days

Another area increasing the utilization of HANARO is the fuel irradiation tests to develop the new fuels. In 1996, the first LEU U_3Si fuel produced by an atomization process was fabricated into a mini-assembly. After the irradiation test of this one, the full-length bundle test was performed. From the results of these irradiation tests, HANARO fuel manufacturing facility was completed on May 2004 and a local manufacturing of the HANARO fuel started[3]. A qualification program for a rod type fuel of the atomized U-Mo was initiated in 2000[4]. The first and second irradiation tests were carried out in 2001 and 2003. The third test started in 2006 and was finished in 2007.

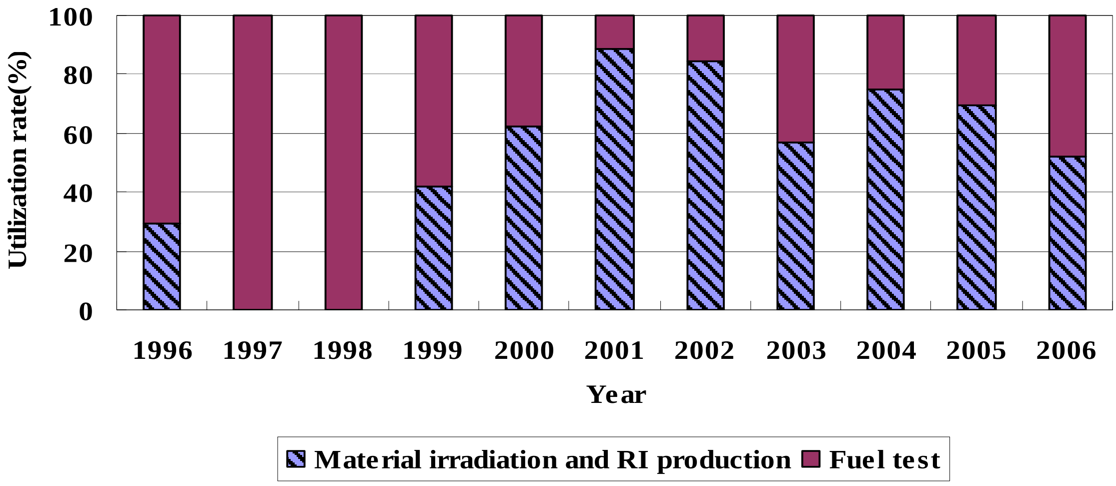

FIG. 4. The ratio of the irradiation materials for the total irradiation

The U-Mo fuel irradiation tests will contribute for a new fuel development for a research reactor. KAERI has been developing a small and medium reactor, SMART for an electricity generation and sea water desalination. U-Zr fuel was adopted for the SMART reactor. The first irradiation test of U-Zr fuel with three 8.1w/o enriched fuels and the second test with three 8.9 ~ 10.0 w/o fuels were completed. The third test had been performed with 19.75 w/o fuels from 2004 to 2006. As a power reactor fuel, a large grained UO_2 pellet has been developed for a high burn-up in KAERI. Two test assemblies are loaded in the upper and lower positions of a capsule. The test assembly of the upper position was unloaded for PIE (Post irradiation examination) and the lower position assembly will be irradiated by a burn-up of 70 MWD/kgU. KAERI has been studying DUPIC fuel through international co-operative research together with CANADA, U.S.A. and IAEA. At present, irradiation tests of DUPIC (Direct Use of spent PWR fuels in CANDU reactors) fuel have been conducted 6 times. Through the DUPIC irradiation tests, the thermal behavior of the DUPIC pellet was analyzed and the technology for a remote assembling and handling has been developed.

On the basis of the experiences of the fuel irradiation test, FTL (Fuel Test Loop) has been installed in the core(IR1 hole) to extend the utilization of the fuel irradiation. FTL is a test facility that irradiate the three fuel pins for PWR and CANDU fuel under the environments of a commercial power reactor with a high pressure and temperature. After a commissioning for a verification of the design performance, it will operate from 2008 with the three fuel pins of PWR fuel.

The irradiation for producing the radioisotopes with a short half life and NTD silicon has been performed in the irradiation holes at the reflector tank. HANARO has two NTD holes. Now, the NTD-2 hole is used for an irradiation of NTD silicon and the equipment is being developed for using the NTD-1 hole. 3 or 4 IP holes are used for a RI production. Some IP holes are not used for several reasons. The IP holes near the NTD-2 hole are not used because when the irradiation material is inserted into the hole the neutron flux distribution can be distorted. IP holes near the control rod facility are also not used. In these holes, a void aluminum plug is loaded to prevent reduction of the thermal neutron by water in the hole.

3. Conclusion

When the HANARO started its first power operation, the utilization of the irradiation holes was inactive. With the simple non-instrument capsules and development of instrument capsules for fuel and material tests contributed that the users can use the HANARO with ease. The Ir-192 production and the facility for irradiating NTD silicon makes the utilization of the irradiation holes in the core and reflector tank more effective and continuous.

Recently, the usage time of the irradiation holes in the core was more than 90% of the reactor operation day. If the FTL starts an irradiation service, the irradiation holes in the core will be fully used. If the utilization of some IP holes in the reflector tank is raised, the HANARO could provide a better service to users.

ACKNOWLEDGEMENTS

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